VOLUME III

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# 30/20 GHz FIXED COMMUNICATIONS SYSTEMS SERVICE DEMAND ASSESSMENT

*by: R. B. GAMBLE*
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*K. M. SPETER*
*M. WESTHEIMER*

*prepared for:*

NASA

LEWIS RESEARCH CENTER



U.S. TELEPHONE AND TELEGRAPH CORPORATION ITT

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NASA Project Manager, William Poley, NASA Lewis Research Center, Cleveland, Ohio

16. Abstract

Demand for telecommunications services is forecast for the period 1980-2000, with particular reference to that portion of the demand associated with satellite communications. Overall demand for telecommunications is predicted to increase by a factor of five over the period studied and the satellite portion of demand will increase even more rapidly. Traffic demand is separately estimated for voice, video and data services and is also described as a function of distance traveled and city size.

The satellite component of projected demand is compared with the capacity available in the C and Ku satellite bands and it is projected that new satellite technology and the implementation of Ka band transmission will be needed in the decade of the 1990's.

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# FOREWORD

This annex to Report CR159620 was produced under NASA Contract NAS 3-21366 titled "30/20 GHz Fixed Communications Systems Service Demand Forecast." The annex contains two sections. The first presents the results of a literature survey conducted under Task 1 of the contract. Several studies projecting various aspects of communications demand are reviewed and comments on their applicability to the 30/20 GHz demand forecast are presented.

The second section of this annex deals with projected costs for 30/20 GHz Satellite Trunking Systems and compares these with the costs of terrestrial communications.

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# LITERATURE SURVEY

## LITERATURE SURVEY

Studies forecasting the communications market in the United States have been prepared by a number of organizations, including market research groups, government agencies, and potential common carrier companies. The following material reviews these forecasts and comments on their applicability to assessment of demand for the 30/20 GHz Fixed Communications System.

The studies that are reviewed and analyzed include:

1) Arthur D. Little, Inc., "Business Communications, 1975-1985."

2) Commission on Postal Service, "Report of the Commission on Postal Service, Volume I."

3) Frost and Sullivan, "The CATV Market."

4) Future Systems, Inc., "A 25 Year Forecast for Commercial Communications Satellites and the Congestion of the Geostationary Arc."

5) Future Systems, Inc., "World Environment and Satellite Communications 1978-2003."

6) Goddard Space Flight Center, "Public Service Communication Satellite User Requirements Workshop."

7) International Resource Development, Inc., "Telecommunications Market Opportunities in the United States."

8) Satellite Business Systems, "Amendment to Operational System Applications to the FCC."

9) Stanford Research Institute, "Technology Assessment of Telecommunications/Transportation Interactions, Volume II. Detailed Impact Analyses."

10) Xerox Corporation, "Petition for Rule Making before the FCC."

ARTHUR D. LITTLE, INC.
May 1975

## BUSINESS COMMUNICATIONS, 1975-1985

### SUMMARY

"Business Communications, 1975-1985," was prepared by Arthur D. Little, Inc. (ADL)" in May 1975 and provides a projection of business communications requirements for the decade of 1975 to 1985. Significant changes in the telecommunications market are predicted due to the rapid advancement in the technology affecting the communications and data processing industries. Also, the loosening of the traditional regulatory restrictions by the Federal Communications Commission (FCC) is encouraging the emergence of new specialized common carriers and valued added carriers who are gearing their offerings to the business user, and, particularly, the digital data user. Other driving forces spurring telecommunication traffic requirements are the rapidly increasing cost of fuel, resulting in less business travel, and the increased cost of mail service.

ADL believes that AT&T will continue to be the dominant force in this nation's communications industry throughout the foreseeable future, although they anticipate substantial growth by non-AT&T companies. The authors contend, however, that the large investment required in operating plants will either drive out the smaller, less financially capable companies, or cause their acquisition by larger companies.

Communication satellites are viewed by ADL as offering the necessary flexibility, high bandwidths, and low costs needed by the newly emerging business communication carriers. The report contains a discussion of the applicable technology in the satellite area as well as that of terrestrial systems.

### DESCRIPTION

The Arthur D. Little report does not attempt to make forecasts to the year 2000, but, rather, limits its sights to one decade, 1975 to 1985. It should be noted that the report was published in May 1975 and, therefore, the base year of 1974 is used as the starting point for its predictions. With acknowledgment given to these limitations, it does appear that the authors provide reasonably good insights into the underlying factors which will affect the telecommunication environment for the remainder of this century.

The growth rate of voice communications in the United States is viewed by the authors to be stable at about 5.5 percent. The voice communication area

anticipated as having the greatest growth potential in relation to businesses is that of audio conferencing. This is due to the escalating costs for travel and the relative high cost of the alternate mode of video conferencing.

A much higher growth rate is predicted for data traffic, although this mode of communication starts from a considerably smaller base than voice communications. Using 1974 as a base year, data communications revenues are estimated to be one billion dollars per year in comparison to voice telephone revenue estimated to be 15 billion dollars per year based on 200 billion calls. The growth rate for data communications traffic, measured in bits transmitted, is anticipated to be 30/40% per year during the report's projection period, 1975 to 1985. ADL feels that this growth rate is conservative in comparison to other generally cited sources.

Another cut at projecting data communications growth is obtained by the anticipated growth in communicating data terminals.* 330,000 Bell-owned data terminals were in operation by the end of 1974, representing an overwhelming majority of data terminals in use on both the switched telephone system and private lines. A good measure of the number of non-Bell data terminals in use can be obtained from the count of Bell-supplied interface devices provided for connection of 77,000 customer-provided data terminals served by the switched telephone network. In addition to these figures, the independent telephone companies served approximately 20,000 data terminals, bringing the total number of data terminals in use by the end of 1974 to 427,000. It should be noted that this total does not include customer-provided data terminals in use on private lines. The increase in the number of data terminals has been growing at a rate of 15 to 20 percent per year.

The interconnection of data processing computers to communications facilities is also expected to increase substantially during this period. ADL estimates that about 35 percent of data processing computers are involved in teleprocessing and they expect the number to reach 70 to 75 percent within five years, increasing communicating computers from approximately 22,000 to 60,000. The increase in teleprocessing computers will tend to increase the transmitted data rates which are relatively low as of the time of the report. ADL estimates that 75 percent of all installations operate at 1200 bits per second or lower.

*While not explicitly defined in the study, it appears that the term "data terminal" is being used to refer to modems.

The lower speed Telex and TWX services still account for a large share of the data communications market. ADL estimates that there are 100,000 Telex/TWX terminals in the United States with a dollar-based growth rate of 4 to 6 percent per year.** Also, since Telex is internationally standardized, a large share of data communications between North America and the other continents, (particularly Europe), employ this mode. The growth rate, however, appears to be stable and lower than other emerging digital media.

Facsimile, on the other hand, is expected to greatly increase from a relatively low user base because of its inherent flexibility for transmitting images such as graphics, signatures, business forms and letterheads. In the past the low transmission speed, relative high cost, and proliferation of incompatible terminals have held back the growth rate of facsimile terminals. ADL estimates the number in use at the end of 1974 to be approximately 40,000. They predict, however, a nearly five-fold increase by 1980.

A very significant variable is the potential of video conferencing. The ADL report indicates that the current user-base for this service is negligible because of the high cost and lack of large bandwidth local distribution facilities. AT&T's attempt to offer video communications through their Picturephone service has not been a success. ADL predicts that video communications service will remain limited at least until the early 1980s. The future of video communication appears to be tied to the energy crisis and, as a result, the cost of business travel. It is impossible to predict with any precision when the cost for fuel will cause the trade between video communications and business travel to be favorable to communications. ADL believes that it is unlikely that we will see any significant growth in video communication until at least 1985.

**Constant 1974 Dollars.

ARTHUR D. LITTLE, INC.
May 1975

In discussing the communications market, estimates of common carrier revenue for various services are given for 1974 and projected for 1980 as follows:

Common Carrier Revenue from U.S. Business and Government in Billions of Dollars (const. 1974 dollars)

| | 1974 | 1980 |
|---|---|---|
| WATS | 1.16 | 2.5 - 3.0 |
| Telex/TWX | .20 | .25 - .28 |
| Private Line[1] | 1.30[2] | 2.0 - 2.5 |

Notes:

1. 80-85% voice grade, 15-20% subvoice and wideband data as of 1973 (Excludes broadcast TV and audio.)

2. Toll portion 85-90% of total, of which 40-45% are are derived from bulk Telpak rates.

Some useful historical data for private line service is included. The total U.S. private line market, including broadcast, was over 1.5 billion in 1974. About 85% (1.334 billion in 1974) is accounted for by AT&T Long Lines and Bell operating companies. Historical growth for this segment is presented below.

ARTHUR D. LITTLE, INC.
May 1975

ATT Private Line Revenues
(Millions of 1975 Dollars)

| | 1970 | 1972 | 1974 |
|---|---|---|---|
| Local | 126 | 147 | 176 |
| Toll | 889 | 1,006 | 1,158 |
| TOTAL | 1,015 | 1,153 | 1,334 |

Note: Includes about $250 million in annual revenues from audio and video program distribution.

| | |
|---|---|
| About 80 - 85% | Voice-grade lines |
| 10 - 12% | Telegraph-grade lines |
| 5 - 8% | Wideband data above 9600 bps |
| 25% | Arise from data transmission at all speeds, expected to grow to 45-55% by 1980 |

COMMENTS

The technology assessments and predictions presented in the ADL report appear to us to be reasonable. Growth rates based on recent history are documented; however, there is little or no basis given for the predictions other than the judgment of the authors. No demographic or other type of model appears to have been used or referenced as the basis of the ADL projections.

A shortcoming of the report for our purposes lies in the fact that it deals with projections for the decade from 1975 to 1985, since the report was published in May of 1975. The report is useful, however, in providing a near term data point for use in comparison with other predictions.

COMMISSION ON POSTAL SERVICE
April 1977

## REPORT OF THE COMMISSION ON POSTAL SERVICE VOL. I

### SUMMARY

This report considers the problems facing the U.S. Postal Service and recommends actions for their resolution. The report includes data and projections through 1985 of costs, volumes, and the impact of electronic communications.

### DESCRIPTION

Of particular interest are Chapter 3, "The Impact of Electronic Communications," and Chapter 4, "Financing the Postal Service." An A. D. Little report in support of the Commission's efforts advises that by 1985 23% of first class mail will have been diverted to electronic communications. The following numbers are cited for 1985:

| | |
|---|---|
| USPS First Class Volume | 56 billion pieces |
| Diverted Volume | 17 " " |
| Total | 73 billion pieces |

Eighty percent of first class mail today is business related (i.e., invoices, bills, payments, statements, purchase orders, financial papers, and business letters). Christmas and greeting cards account for more than 10 percent. Personal letter correspondence is only 3 percent.

Financial transactions are most vulnerable to diversion. Fifteen percent of all treasury payments are now (1977) deposited automatically into bank accounts. The total first class mail diversion due to electronic fund transfer systems is estimated at 1.9 billion pieces by 1980 and 6.6 billion pieces by 1985.



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COMMISSION ON POSTAL SERVICE
April 1977

Two forecasts are made of mail volumes and postal rates through 1985 (fiscal years) based on (a) A Business-as-usual posture; (b) New public service appropriations equal to 10% of the prior year's cost.

| | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|---|---|
| (a) Business-as-Usual | | | | | | | | | |
| 1st Class Rate (¢/oz) | 13 | 16 | 16 | 18 | 20 | 22 | 23 | 26 | 28 |
| 1st Class Vol. (Bil.) | 52.7 | 51.2 | 52.0 | 52.5 | 52.3 | 51.8 | 51.4 | 50.3 | 48.7 |
| (b) 10% Appropriation | | | | | | | | | |
| 1st Class Rate (¢/oz) | 13 | 13.8 | 14 | 15 | 16 | 17 | 19 | 20 | 22 |
| 1st Class Vol. (Bil.) | 52.7 | 54.1 | 55.2 | 55.8 | 56.0 | 55.6 | 55.1 | 54.2 | 52.6 |

COMMENTS

The report is useful in providing volume estimates for potential electronic mail applications. The volume of first class mail projected appears in either of the above scenarios to remain relatively constant with time at a rough level of 50 billion pieces per year. Using the factor of 80 percent quoted as appropriate to business mail brings this to 45 billion per year. An additional factor would be required to separate that portion of mail that travels a long distance as opposed to local mail. The rate figures quoted may be useful in permitting estimates of cost/volume elasticity.

FROST & SULLIVAN
June 1978

# THE CATV MARKET

## SUMMARY

The CATV industry has been active in the U.S. for over twenty years. Until recently, CATV was situated in areas with poor TV reception. More recently, however, CATV has been penetrating larger cities and better reception areas due to the introduction of original programming. This development is a result of the availability of low-cost earth stations and a cheap satellite delivery system. The last two years have seen an explosive growth in the number of CATV program originators and earth station installations.

In this report Frost and Sullivan examines all the aspects of the market, from subscribers to programmers to suppliers. The report summarizes the situation to date, forecasts some variables to 1986 and analyzes the various factors that impact on the CATV market.

## DESCRIPTION

Between 1950 and 1960 the penetration of households with television has increased from 9 percent to 87 percent. The rise in the number of CATV subscribers from 1965 to 1975 shows an even steeper growth curve (18.7 percent average annual growth). Pay TV program originators, with nationwide coverage, have also increased greatly in the past two years. Largely as a factor of low satellite transponder costs charged by RCA Americom, the number of program originators has grown to include:

1. HBO
2. Showtime
3. Madison Square Garden
4. United Press International

Additionally, a number of independent TV stations, with a great deal of movie or sports programming, have started to use the satellite to expand their viewing audience (and hence charge higher advertising rates). These "super stations" include:

1. WTCG - Atlanta
2. WKTVU - San Francisco
3. WGN - Chicago
4. WKTLA - Los Angeles

A number of religious networks have also gone to the satellite to increase their potential audience, among them:

1. Christian Broadcasting Network
2. People that Love Network
3. Trinity Broadcasting Network

Basic CATV subscription households are forecasted to more than double from 1977 to 1986, and pay TV subscribers are expected to rise six-fold in the same time frame, with total CATV system revenues tripling from 1977 to 1986.

COMMENTS

This report offers a good overview and background information of the industry and includes some analyses of factors that would impact the CATV market. However, the report has two basic drawbacks with respect to the NASA project:

1. The forecast period does not go beyond 1986.

2. Whatever forecasts are projected, they are in terms of subscribers, revenue or equipment. The critical factor for the NASA project is that of channel utilization by program originators.

FUTURE SYSTEMS INC.
Nov. 1977

# A 25 YEAR FORECAST FOR COMMERCIAL COMMUNICATIONS SATELLITES AND THE CONGESTION OF THE GEOSTATIONARY ARC

## SUMMARY

This report forecasts usage of the geostationary orbital arc for commercial communications satellites. It includes a forecast of global traffic over the 25 year period 1977 to 2002. The primary contributors to this traffic are:

a. Telephony
b. New Data Services
c. TV Distribution
d. Video Conferencing
e. Direct TV Broadcast
f. Aeronautical and Maritime Services

Requirements for each of the above services are related to GNP which is then used to extrapolate from nation to nation and into the future. The report treats global requirements, but the discussion below focuses primarily on results presented for North America.

## DESCRIPTION

The forecast for telephony is essentially based on the following steps:

1. Extrapolate GNP per telephone. For North America (i.e., USA and Canada) in the year 2002, this is projected to be $10,000 per telephone. Sources are stated to be ITU's "Handbook on Telephone Statistics," ATT's "The Worlds Telephones" as of Jan. 1976, and IMF's "International Financial Statistics." Data from these sources was manipulated, smoothed and extrapolated to the year 2002.

2. Extrapolate the number of long distance calls per telephone. (Sources not clearly stated, but presumed to be included in above.) For North America in the year 2002 this is estimated at 120 LD calls per telephone per year.

3. Calculate number of LD calls per $1000 GNP. For North America in the year 2002, this is estimated as 12 calls per year per $1000 GNP.

4. Multiply by GNP (in 1977 dollars). The GNP in 2002 is projected to be $380 billion. The result is 45 billion long distance calls per year.

5. Translate long distance calls per year into call minutes by assuming 9 minutes per call. Result for North America in year 2002 is 405 billion call minutes/year.

6. Find percentage of LD calls suitable for satellite transmission. In North America, based on 500 mile break even distance with respect to terrestrial network costs, this is estimated at 8%. Result for year 2002 is 32 billion satellite call minutes/year.

7. Convert call minutes to circuits by assuming 2400 busy hours per year and 80% circuit loading. Result for North America in year 2002 is 278,000 circuits.

8. Convert to number of "nominal" transponders on basis of 1 transponder per 1000 one-way or 500 two-way circuits. Result for North America in year 2002 is 560 transponders needed to support telephony.

In addition to the above an allocation is made for New Data Services. The approach is based on SBS's April, 1976 Filing with the FCC. This states that 415 major U.S. corporations are expected to create a market for 90,000 voice and 100,000 data circuits for transmission by satellite by 1985. Additional contributions from smaller corporations and government are also anticipated. This would require roughly 200 transponders. The Future Systems Inc. report cuts this estimate in half and extrapolates from 1985 to 2002 in proportion to GNP. (One transponder per $20 billion GNP). Result for North America in year 2002 is 190 transponders.

To account for TV Distribution the report estimates U.S. requirements in 2002 to be 60 TV channels which can be carried on 30 transponders. Tying this to GNP the factor is 1 transponder for each $110 billion of GNP. This is then used to arrive at the North American total (U.S. plus Canada) by multiplying by the projected year 2002 North American GNP of $3800 billion. The result is 35 transponders capable of supporting a total of 70 TV channels.

Video Conferencing is emphasized as a growing contributor to demand because of the rising cost of travel linked to depleting oil reserves. The report predicts a peaking in oil consumption in 1995, at which point about 50 percent of the world's oil supply will have been consumed. Thereafter, consumption will decline with 97 percent of the world's initial reserves being consumed by the year 2050. A video conferencing demand is postulated for the replacement of 15 percent of U.S. air travel (plus an additional 5 percent of the air travel allocated to new service applications which are not direct substitutes for travel). This predicted demand is then related to GNP (about one video channel per $100 million GNP). The result is a North

FUTURE SYSTEMS INC.
Nov. 1977

America, year 2002, requirement for 38,000 Video Conferencing circuits. The report discusses the inadequacy of present satellite systems to provide this capacity and suggests the need for special purpose, high capacity video satellites operating in the 12/14 and 18/30 GHZ bands. Allowing for a high level (20 times) of frequency reusage and a 4 to 1 improvement in coding technology, a capacity of 8000 to 10,000 two-way video circuits per satellite is predicted.

An additional allocation for Direct TV Broadcast is made with particular reference to educational purposes. For North America in the year 2002, ten Direct TV Broadcast channels are projected.

The report also briefly considers Aeronautical and Maritime services. Atlantic and Pacific Maritime Traffic in the year 2000 is projected to require respectively 360 and 180 equivalent voice channels. Air traffic over each of these two oceans will account for an additional 15 Voice channels.

COMMENTS

The procedure used in this report is basically to relate long distance telephone calls (some fraction of which are assumed to be routed via satellite) to GNP. Projections of satellite traffic into the future, and translations of traffic volume from nation to nation are then accomplished in terms of the GNP appropriate to the time and place in question. The traffic projections, therefore, cannot be any more valid than the projection of GNP on which it is based. Furthermore, it is not clear, despite data presented in the report, that the ratio of long distance telephone traffic and GNP is stable from country to country and from year to year. Another uncertainty relates to the assignment of a suitable fraction of long distance telephone traffic to satellite facilities.

Despite these difficulties, the procedure followed is useful in providing one more means of assessing future telephone traffic demand for satellite channels.

A substantial number of channels are predicted for new data services. These are based on SBS projections reduced by a factor of two. Comment is reserved for the discussion of the appropriate SBS reports.

FUTURE SYSTEMS INC.
Nov. 1977

With respect to Video Conferencing requirements, the method used (displacing some fraction of the projected air travel by communications) is a valuable approach. The estimate that 20 percent of such travel will be replaced is not unreasonable, but it would be desirable to find some independent measure to support this. The assumption that this 20 percent will be replaced entirely by video conferencing as opposed to lower bandwidth approaches such as audio supplemented by facsimile or slow scan TV, however, is more open to question. Replacement of 20 percent of air travel by video conferencing would, according to this report, require 38,000 video channels for North America in the year 2002. This is a very large number and would require the development of special purpose high capacity satellites, with particular reference to the use of the 18/30 GHZ band, and high technology data compression and spot beam transmission. A more reasonable assumption might be that only a small fraction of the traffic demand will be satisfied by video conferencing and that much of the requirement will be handled by narrowband teleconferencing facilities.

FUTURE SYSTEMS, INC.
May 1978

## WORLD ENVIRONMENT AND SATELLITE COMMUNICATIONS 1978-2003

### SUMMARY

This report follows up and expands the material contained in FSI's Report 103. The procedures used (based on GNP related projections) were described in the review of Report 103 and are not repeated here. Report 104, however, in addition to sliding the time frame forward by one year, also provides a more detailed breakdown by year. The report describes global requirements, but only the components applicable to North America (U.S. and Canada) are included below.

### DESCRIPTION

The following projections for North America are of interest. Results are stated in terms of thousands of one way equivalent voice channels which are equated in this report to be roughly equivalent to the capacity of one transponder.

1. Population and GNP

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| Population ($\times 10^6$) | 244 | 253 | 262 | 271 | 281 | 292 |
| GNP, 1978 Dollars ($\times 10^9$) | 2191 | 2508 | 2863 | 3269 | 3742 | 4306 |

2. Telephony

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| Long Distance Calls ($\times 10^9$) | 13.8 | 19.9 | 27.0 | 34.5 | 42.3 | 51.1 |
| Percent via Satellite | 4.0 | 6.5 | 7.5 | 7.8 | 7.9 | 8.0 |
| Satellite Call Minutes ($\times 10^9$) | 5.0 | 11.7 | 18.1 | 24.2 | 30.2 | 36.7 |
| Satellite Voice Traffic (Voice Ch. $\times 10^3$) | 87 | 204 | 315 | 421 | 525 | 638 |

3. Data Transmission

These represent new computer technology related applications in addition to that extrapolated from historical use. Estimates are based on one-half of SBS's projection of 100,000 equivalent voice channels for data by 1985, and then extrapolated by relating to expected GNP.

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| New Data Trans. Req. (Equiv. Voice Channels x $10^3$) | 0.0 | 57 | 114 | 151 | 182 | 213 |

4. TV Distribution

This includes network TV, CATV, Home Box Office, etc. The results are stated to be conservative by as much as a factor of two when additional uses related to education and cultural exchange programs are considered.

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| TV Distribution Req. (Equiv. Voice Channels x $10^3$) | 13.9 | 20.3 | 25.0 | 29.3 | 33.8 | 39.1 |

5. Video Conferencing

Based on 15% displacement of air travel, plus an additional 8000 video channels for non-travel related applications. It is postulated that advanced compression techniques will permit the transmission of a video channel in the equivalent of 100 voice channels. The future use of special high capacity satellites capable of 8000 two-way video circuits per satellite is referred to, and is discussed further in FSI Report 103.

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| Video Conferencing Req. (Thousands of Video Circuits) | 0.0 | 0.0 | 7.4 | 18.0 | 27.2 | 35.9 |

## 6. Satellite Costs

The report projects costs for Intelsat channels by year, and then repeats the calculation for a hypothetical country of fifty million with 1978 GNP per capita of $1,150. It is assumed that operation commences in 1982 and grows to 32 transponders by 1994. Values are in 1978 dollars. While neither example is directly applicable to the domestic U.S. situation, the results are of order of magnitude interest and the procedures used can be extended to cover other cases.

Cost per One Way Equiv. Voice Circuit ($ x $10^3$)

| | 1978 | 1983 | 1988 | 1993 | 1998 | 2003 |
|---|---|---|---|---|---|---|
| INTELSAT Circuit Costs | 7.5 | 3.2 | 1.8 | .8 | .5 | .3 |
| Small Domestic System Costs | - | 10.6 | 5.2 | 2.0 | - | - |

COMMUNICATIONS AND NAVIGATION DIVISION
GODDARD SPACE FLIGHT CENTER

## PUBLIC SERVICE COMMUNICATIONS
## SATELLITE USER REQUIREMENTS WORKSHOP

### SUMMARY

A workshop was held, October 17-19, 1976, to analyze user requirements for public service communications. The workshop examined requirements for: commercial services, data and message services, education, environmental, medical, public safety, religious, governmental and voluntary service communications.

After having determined that various needs exist, the panels felt that a market validation effort should take place. The market would be established and verified through an actual demonstration approach. Furthermore, the panels suggested that NASA should consider various alternatives in establishing a quasi-operational system including:

(1) Use existing communications capabilities (space segment, ground terminals, terrestrial links)

(2) Provide incentives for industry to develop the services (policies, taxes, subsidies, etc.)

(3) Use a Government system in cooperation with commercial services (rent capability from industry)

The report includes 13 chapters, one on each of the thirteen services, and nine appendices.

### DESCRIPTION

Primary and Secondary Education, as well as Continuing Education and Medical Education, have been analyzed by three different panels in the workshop. Based on present communication applications such as the Catholic TV Network, the Primary and Secondary Education Panel described various requirements including: access to specialized education to the household, students facilitation of enrichment activities, as well as teacher education and teleconferencing for a variety of other teachers' needs. The panel on continuing or extension education considered the needs for education by: Correctional Institutions, Military Training, and Business and Industry. The Medical Education Panel studied telediagnosis and public health education. Other panels studied the areas of Medical Services and Public Safety, as well as Religious and Governmental user applications.

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The workshops considered different types of communications including: voice, record, data facsimile and video. The various panels estimated user requirements for video channels as follows:

| | | |
|---|---|---|
| Primary and Secondary Education | 20-25 channels | (1) |
| Continuing Education | 3 channels | (2) |
| Biomedical | 55 channels | (3) |
| Religious | 4 channels | (4) |
| Public Service (disaster, law enforcement, etc.) | 8 channels | (5) |

Source:

(1) Washington University Study
(2) Continuing Education Panel
(3) CCIR Report
(4) Religious Application Panel
(5) Public Safety Panel

COMMENTS

This report includes extensive information on the various requirements by public service type users. It includes an overview of activities and studies that have been conducted in a number of different areas, as well as attempts to estimate some qualitative and quantitative user needs.

The major drawbacks of the workshops report involve: (1) the lack of a clearly defined time dimension for its forecasts; and (2) lack of coordination and consistency between the various panels. This lack of a consistent format or approach creates difficulties when, on a macro level, one attempts to aggregate different user needs.

Overall, the report provides a great deal of background information and some quantified forecasts for a number of different user groups. It thus provides a basis for forecasting market requirements in a number of different areas.

INTERNATIONAL RESOURCE DEVELOPMENT, INC.
April 1978

# TELECOMMUNICATIONS MARKET OPPORTUNITIES IN THE UNITED STATES, 1978

## SUMMARY

This report presents a comprehensive overview of the U.S. Telecommunications market as it existed in early 1978 and as projected to 1988. The viewpoint is market oriented, with projections of value/revenue provided for the following segments of the industry:

Telephone Carrier Services
Telecommunications Plant and Equipment
Specialized Common Carriers
Domestic Satellite Carriers and Equipment Suppliers
Data Communications Terminals and Equipment
Electronic Message Systems and Value Added Networks
Business and Consumer Interconnect Equipment
Facsimile Equipment Markets
Personal/Mobile Communications
International Telecommunications
FFT Systems and Financial Information Services
Multipoint Distribution Services

## DESCRIPTION

The estimates presented in this report are generally supported by qualitative argument only so that the validity of the results cannot be readily judged. As in most market oriented surveys, attention focuses chiefly on dollar sales that may be expected in various market segments. Of the market segments listed in the summary above, the fastest growing is Satellite Carriers, which is expected to have an annual growth rate of 34% over the 1978-1988 decade. Very large growth rates are also projected for Value Added Networks (28% per annum) and Specialized Carriers (20% per annum). All of the projections are given in constant 1978 dollars, and therefore do not include inflationary factors.

The report states that satellite communications is on the verge of explosive growth, but that growth to date, while rapid, has not taken place as quickly as anticipated. The argument advanced to explain this is that data communications switchover to satellite has been hampered by the delay problem as it impacts the transmit/acknowledge handshaking employed in bisynch protocol. This is currently the most commonly used protocol, and many users are reluctant to undertake the software conversion necessary to implement a more suitable

protocol. The impact of this is more far reaching than would be the case for data transmission alone, since in many cases the users want to use their leased voice-grade channels for both voice and data, and lack of a suitable solution to their data transmission requirements thus impacts on the approach taken for voice. Delay compensation systems that provide external buffers for the elimination of the delay problem are now offered by several manufacturers (priced at a few thousand dollars) and provide an interim approach pending adoption of newer protocols. The growth projected for the Satellite Communications Market is summarized below:

Projected Satellite Communications Markets 1978-1988

| | 1978 | 1980 | 1983 | 1988 |
|---|---|---|---|---|
| Private Line Revenues ($ x $10^6$) | 30 | 60 | 200 | 1100 |
| Broadcasting Revenues ($ x $10^6$) | 40 | 65 | 90 | 200 |
| Satellite Shipments (Units) | 2 | 5 | 8 | 5 |
| Rec. Only Earth Sta.(Units Shipped) | 2000 | 3600 | 7700 | 12000 |
| Trans/Rec. Earth Sta. (Units shipped) | 50 | 350 | 525 | 1400 |

The receive only earth stations referred to in the table above are used primarily in broadcasting. Most of these units are expected to be low cost (below $2000) radio receiving earth stations. The transmit/receive earth stations are expected, by the late 1980s, to include as many as 1000 small rooftop units shipped to ATT and other carriers.

Also discussed in the report is a ten year projection of the market for telephone carrier services. Toll services are expected to show only minor growth patterns and are described in terms of the following segments.

Telephone Toll Service Revenues ($ x $10^6$)

| | 1978 | 1988 | Avg.Annual Growth % |
|---|---|---|---|
| Message Toll | 19,741 | 30,066 | 4.3 |
| WATS | 2,100 | 2,660 | 2.4 |
| Private Line (Conventional Carriers) | | | |
| Telephone | 699 | 802 | 1.4 |
| Teletypewriter | 75 | 45 | (-5.0) |

Telephone Toll Service Revenues ($ x $10^6$) (Cont.)

| | 1978 | 1988 | Avg.Annual Growth % |
|---|---|---|---|
| Telegraph | 3 | - | -- |
| Telpak | 715 | 790 | 1.0 |
| Program Trans. (Audio & Video) | 80 | 30 | (-9.4) |
| Other | 288 | 318 | 1.0 |

The projected market for specialized common carriers in contrast shows rapid expansion for most segments as presented below:

Projected Market for SCC Services ($ x $10^6$)
(excluding Satellite Carriers)

| | 1978 | 1988 | Avg.Annual Growth % |
|---|---|---|---|
| Message Toll Service | 75 | 700 | 25.0 |
| Leased Voice Lines | 55 | 125 | 8.6 |
| Broadcast | 10 | 5 | (-6.7) |
| Other | 5 | 30 | 19.6 |

Some insight into data communications developments are possible from projections offered for the Data Communications Terminal Market.

Projected Data Communications Terminals Shipped

(Number of Units x $10^3$)

| | | 1978 | 1988 |
|---|---|---|---|
| Dumb CRTs | | 150 | 75 |
| Teleprinters and Communicating Word Processors | | 180 | 540 |
| Intelligent Terminals | | 50 | 350 |
| | TOTAL | 380 | 965 |

INTERNATIONAL RESOURCE DEVELOPMENT, INC.
April 1978

Another market segment treated is the potential market for Electronic Message Services and VANS.

Projected Market for Electronic Message Service and VANS ($ x $10^6$)

| | 1978 | 1988 |
|---|---|---|
| Telex/TWX | 245 | 325 |
| Mailogram | 60 | 180 |
| Facsimile (Carrier Revenues) | 100 | 450 |
| Telegram | 55 | 20 |
| Packet Switching Nets | 30 | 350 |
| Special Services | 3 | 30 |
| Money Orders | 48 | 60 |
| Faxgram | 9 | 20 |

A considerable discussion is provided relative to Facsimile, whose carrier revenues are projected above to show an annual growth rate of about 16 percent. The following gives a breakdown in terms of the projected number of facsimile units shipped per year.

Facsimile Units Shipped

| Type | 1978 | 1988 |
|---|---|---|
| Commercial | | |
| Low Speed (4-6 min./page) | 30,000 | 10,000 |
| Medium Speed (2-3 min./page) | 2,000 | 30,000 |
| High Speed (Sub-minute) | 3,000 | 4,500 |
| Specialty (Newspaper, Photo, etc.) | 2,500 | 4,800 |
| Wideband (56 Kbps and above) | 4,000 | 11,000 |

COMMENTS

The report, as stated earlier, is oriented toward defining the market place in terms of interest to potential manufacturers and service companies. Its utility with respect to demand projection is hampered by a presentation that

emphasizes equipment dollar value rather than the underlying traffic requirement that motivates the estimate. Nevertheless, some data points can be abstracted from the report and may prove valuable as a comparison and calibration of forecasts based on other approaches.

SATELLITE BUSINESS SYSTEMS
April 16, 1976

# AMENDMENT TO OPERATIONAL SYSTEM APPLICATIONS TO THE FCC

## SUMMARY

This Amendment, filed concurrently with a Section 214 application for an Operational System in the 12/14 GHz band, responds to an FCC request for information beyond that contained in SBS's five volume December 1975 Application. Among the requests for information responded to was Item No. 2 dealing with "the estimated demand for each service to be offered and the basis for such estimate." In addition, under Items 5 and 6 dealing with system construction and annual operating costs, the Amendment projects the number of earth stations installed and satellites orbited through 1986.

## DESCRIPTION

The basic communication mode between earth station and satellite is via TDMA demand assignment. Digitized voice, data and image traffic will be time-multiplexed and QPSK modulated to produce a 41 Mbps digital stream for burst transmission to the satellite. Variation in the burst duration will be used to match capacity allocation to the requirements of each station. Each satellite will carry eight, 20 Watt, 54 MHz transponder channels.

SBS conducted a survey of the potential demand of its anticipated users ("large enterprises with large communications requirements"). To accomplish this they examined the Fortune 500 group and the top 50 companies in each of six additional "Fortune" categories. Of the 800 companies represented, 415 were selected as most likely customers for SBS's initial offering. The criteria for selection included company revenue, number of employees, magnitude and type of present communications usage, type and extent of installed information processing capabilities, and geographic dispersion of the company's offices and plants. Demand projections are stated to be based on a conservative estimate of the requirements of these companies. Furthermore, they do not take into account the potential demand of government agencies or smaller commercial enterprises.

In-depth interviews were held with 16 of these companies which were selected as representative of major customer categories in different manufacturing and service classifications. Information was collected concerning projected traffic density and distribution. The information was analysed, combined with other sources, and used to make demand projections beginning in 1979 and continuing through 1986. In making these projections, growth rates of 8% per year for voice and 19% per year for data were assumed.

SATELLITE BUSINESS SYSTEMS
April 16, 1976

Results are presented in terms of the following communications services:

a) Voice - Delta modulated digital at 32 KBps*

b) Low-Speed Data - 600 Bps to 19.2 KBps

c) Medium-Speed Data - 56 KBps to 896 KBps

d) High-Speed Data - 1.344 MBps to 6.312 MBps

Table 1 shows demand projections for earth station access ports for each of the above services.

Table 2 shows satellite capacity needed to satisfy demand for each service.

Table 3 summarizes the previous figures.

The demand for total satellite capacity in equivalent voice circuits (probably 50,000 bps) as presented in Table 3, is obtained by summing the voice and data requirements of Table 2. The derivation of the number of earth stations needed as shown in Table 3 is not presented, but elsewhere in the report (P26) an average earth station is described as supporting a 41 MBps digital rate and including:

51 Voice ports
7 Low-speed data ports
2 Medium-speed data ports
1 High-speed data port for every 3 earth stations

By comparing the two charts of Table 3, it appears that a ratio of 25 equivalent voice circuits per earth station may have been used as a conversion factor for calculating the number of earth stations.

The initial operational system is conceived as requiring two satellites in orbit (8 transponders per satellite), one as a primary and the other as a secondary satellite. There will also be a spare satellite on the ground for replacement purposes. The estimated year-end number of installed earth stations is as follows:

*As per Communication Services Interfaces - SBS 3201-0004 dated Jan. 5, 1978, p.ii. This will also support modem generated analog signals at rates up to 1800 Bps. Some consideration is being given to increasing the rate above 32 KBps.

TABLE 1. DEMAND FOR EARTH STATION ACCESS PORTS (Thousands)

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|
| Voice | 195 | 210 | 228 | 246 | 267 | 288 | 311 |
| Low Speed Data | 25.0 | 29.5 | 35.0 | 41.5 | 49.5 | 59.5 | 70.0 |
| Medium Speed Data | 6.1 | 7.4 | 8.9 | 10.4 | 12.4 | 14.5 | 17.4 |
| High Speed Data | 1.1 | 1.3 | 1.5 | 1.8 | 2.1 | 2.5 | 3.0 |

TABLE 2. DEMAND FOR SPACE CAPACITY
(Thousands of Equivalent Voice Circuits)

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|
| Voice | 58.0 | 63.0 | 68.0 | 73.5 | 79.5 | 85.5 | 93.0 |
| Low Speed Data | 6.3 | 7.3 | 8.8 | 10.5 | 12.5 | 14.8 | 17.6 |
| Medium Speed Data | 8.4 | 10.0 | 12.0 | 14.0 | 16.8 | 20.0 | 23.8 |
| High Speed Data | 18.5 | 22.0 | 26.0 | 31.0 | 37.0 | 44.5 | 53.0 |

TABLE 3. DEMAND FOR TOTAL SATELLITE
CAPACITY AND EARTH STATIONS

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|
| Total Satellite Capacity (Thous. of Equivalent Voice Circuits | 92 | 102 | 115 | 129 | 146 | 165 | 187 |
| Earth Stations (Thousands) | 3.70 | 4.15 | 4.65 | 5.20 | 5.85 | 6.65 | 75 |

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| | NUMBER OF EARTH STATIONS INSTALLED AT YEAR END | | |
|---|---|---|---|
| | 5-Meter | 7-Meter | TOTAL |
| July 1979 (Start of Comml.Ops.) | 18 | 12 | 30 |
| 1979 | 47 | 31 | 78 |
| 1980 | 105 | 69 | 174 |
| 1981 | 163 | 107 | 270 |
| 1982 | 220 | 146 | 366 |
| 1983 | 225 | 150 | 375 |
| 1984 | 225 | 150 | 375 |
| 1985 | 225 | 150 | 375 |
| 1986 | 225 | 150 | 375 |

The leveling off at 375 is due to the fact that this SBS application is only with respect to the initial two operational satellites. The 375 earth stations are expected to fully occupy the initial operational capacity of eight transponders. SBS states that it actually anticipates an installation rate beyond the beginning of 1983 at an annual rate similar to that for the first four years.

COMMENTS

The material presented in Tables 1, 2 and 3 is potentially of interest in projecting satellite demand, but not enough information is presented to allow an independent appraisal of the validity of the analysis procedures used, or of the resultant estimates.

Probably of greatest interest are the estimates for satellite demand in equivalent voice circuits presented in Table 2. The conversion of equivalent voice circuits to bit rates is somewhat uncertain since the factor used is not directly presented. Assuming that 50 Kbps represents a reasonable conversion factor, the information in Tables 2 and 3 can be presented as follows:

SATELLITE BUSINESS SYSTEMS
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| | 1980 | | | 1985 | | |
|---|---|---|---|---|---|---|
| | Equiv.Voice Circuits | MBPS | % | Equiv.Voice Circuits | MBPS | % |
| Voice | 63,000 | 3150 | 61.6 | 93,000 | 4650 | 49.6 |
| Low Speed Data | 7,200 | 360 | 7.0 | 17,500 | 875 | 9.3 |
| Med. Speed Data | 10,000 | 500 | 10.0 | 24,000 | 1200 | 12.8 |
| High Speed Data | 22,000 | 1100 | 21.5 | 53,000 | 2650 | 28.3 |
| TOTAL | 102,200 | 5110 | 100.0 | 187,500 | 9375 | 100.0 |

The composite annual growth rate is 13%, but this simply reflects the weighted averaging of the originally assumed 8% for voice and 19% for data.

The document states that 375 earth stations are expected to fully load a single satellite having 8 transponders. Thus, each transponder may be presumed to be capable of handling the load generated by approximately 47 earth stations. Using the figure of 25 equivalent voice channels per earth station discussed earlier, SBS must be planning on about 1200 equivalent voice channels per transponder. This corresponds to 1200 x 50,000 = 60 MBps per transponder, or 1.1 bits per Hz in the 54 MHz bandwidth of the transponder, which seems somewhat low when the theoretic capability of QPSK of 2 bits per Hz is considered. Some more recent publications* appear to assume 75 MBps per transponder corresponding to 1.7 bits per Hz, but an accurate evaluation of this factor is of importance only with respect to the actual transponders planned for SBS, and does not influence demand projections in terms of equivalent voice circuits or bits per second.

*Quantum Science "The Future of IBM"

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## TECHNOLOGY ASSESSMENT OF TELECOMMUNICATIONS/TRANSPORTATION INTERACTIONS VOLUME II. DETAILED IMPACT ANALYSES.

### SUMMARY

This report identifies and analyzes the social, economic, environmental, and quality of life impacts that may result from a substitution of transportation by telecommunications. Three types of scenarios were developed including:

1. Use of two-way audio or audio/video teleconferencing as a substitute for business travel.

2. A dispersion of offices and business activity away from central business districts to suburban locations.

3. The use of teleconferencing and "office automation" to enable future office workers to work at or near their homes.

As a substitute for business travel SRI has estimated that 45 percent of all business trips for meetings can be effectively substituted by audio, graphics, and computer systems. Video conferencing would add about 8 percent more substitution possibilities.

The report includes six impact synthesis papers, twenty-four impact papers, five appendices, and 1,090 entry bibliography.

### DESCRIPTION

Travel and communication interactions involve more than a simple question of economic trade-off. Some managers regard travel as an attractive side benefit, while others have a more negative attitude towards travel. Attitudinal studies toward business travel have indicated that an inverse relationship exists between the desire to travel more, and the current level of travel. A Bell Canada study of 9,619 people who traveled on business has shown that while 31 percent of those who traveled 0-5 times a year had a desire to increase the number of trips (16 percent wanted to decrease), only 7 percent of those who traveled 30+ times a year wanted to increase the number of trips. Overall, 15 percent of the respondents indicated they would want to increase the number of trips, while 37 percent wanted to decrease, and 48 percent stay the same. A private study by Roger Pye of 145 managers and professionals in England had similar results: 7 percent wanted to travel more, 28 percent less and 35 percent about the same (30 percent expressed no opinion).

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Attitudes and perceptions of different teleconferencing media, as well as a substitution for travel, will have an impact on market demand. An investigation of 54 American executives toward audio, video, or face-to-face conferencing has shown that audio conferences were thought to be less friendly than video or face-to-face; video and face-to-face were thought to be equally friendly. Similarly, users of Bell Canada's video conference system and the University of Quebec's audio system have indicated that video was more friendly and more similar to face-to-face than audio conferencing.

A number of studies have been completed as to what type of meeting may be substituted by teleconferencing. One approach examines the activities and objectives of the meetings and utilizes a cluster analysis to segment the results. The three types of media and respective clusters are summarized below.

"EFFECTIVE" MEDIA FOR THE MEETING TYPES
IDENTIFIED BY THE DACOM CLUSTER ANALYSIS

| Fairly Definitely | | Tentatively |
|---|---|---|
| Allocated to face-to-face (face-to-face only is "effective") | | Cluster 1: High scores on most descriptor scales<br>Cluster 5: Conflict<br>Cluster 7: Negotiation<br>Cluster 8: Negotiation & Conflict<br>Cluster 12: Presentation of Report |
| Allocated to video (video and face-to-face only are "effective") | Cluster 10: Forming impressions of others | Cluster 2: Giving information to keep people in the picture |
| Allocated to audio (all media are "effective") | Cluster 4: Decision making<br>Cluster 6: Information seeking and discussion of ideas | Cluster 11: Delegation of work |

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Allocation of Cluster 3, which comprised a mixed residue of widely different types of meetings, has not been attempted. Cluster 9 was a very small cluster of meetings consisting of disciplinary interviews.

Two studies have indicated that 17 percent to 22 percent of meetings are substitutable by audiovisual conferences, and 52 percent to 41 percent substitutable by audio conferences. Based on these studies (allocations corrected for bias) an estimated 45 percent audio and 8 percent audio/video conferences can be a substitute for business travel.

The cost of videoconferencing, as tariffed by ATT, has been compared to the cost of travel. On a simple substitution basis, video is more cost effective for shorter meetings and many traveling participants. Based on the average length of two hours per meeting and two people travelling to attend one meeting, videoconferencing is not cost effective using Picturephone Meeting Service and current travel rates. However, when travel time is costed (even at $5.00 per hour), videoconferencing is cheaper.

Overall, due to several remaining uncertainties, no particular scenario was deemed preferable. However, the possibility of moving information to people rather than people to information, is of sufficient importance to merit widespread consideration by government, industry and the public.

COMMENTS

The study includes a comprehensive and almost exhaustive analysis of teleconferencing and its economic, social, and sociological implication. And while the report serves as a valuable guide for calculating future demand, it contains two major shortcomings:

1. The approach of substitution for travel is a valid starting point. However, when comparisons are made between videoconferencing and travel, future developments have to be considered. In particular: (a) a sharp rise in the cost (time and money) of travel due to increasing fuel costs and overcapacity utilization of airports and, (b) a reduction of videoconferencing cost as a function of increased capacity due to technological innovation.

2. While alluring to the preference that users have for video vs. audio conferencing (with no accompanying cost parameters), the subject of media substitutability is still approached from a real utility point of view. Perceived utility is a powerful factor in determining consumer decisions. Perception is also a function of a number of factors including advertising (marketing), and the alternative ways of filling one's needs.

The report suggests that its quantified results are conservative. This is in view of lack of further detail as to the psychology of the consumer, the strategy of potential appliers, and the scope of direction of technological innovation.

Overall the study offers an excellent outline for quantifying video conferencing market demand. Together with further analysis of information presented in the impact papers and additional inputs from other sources, a basis can be established for calculating videoconferencing market demand.

XEROX CORPORATION
Nov. 16, 1977

## XEROX CORP. PETITION FOR RULE MAKING BEFORE THE FCC

### SUMMARY

The petition requests that the 10.55 - 10.68 GHZ Band be allocated to a new common carrier service referred to as "Electronic Message Service (EMS)". The proposed EMS service is primarily directed toward filling communications needs associated with the office of the future. The network envisioned will use terrestrial microwave links from office rooftops to Local/City nodes. Relay from these Local/City nodes to Earth Stations is also via microwave links. The long distance portions of the network are via satellite transponders leased from current or proposed domestic satellite carriers. Thus, the services and requirements discussed in this filing have direct impact on satellite demand.

Each subscriber to EMS will have access to a transmission rate of 256 Kb/s which is predicted to have beneficial effects on facsimile, data, and teleconferencing activities. Service would be extended to the largest 100 to 200 metropolitan areas (which cover 64% to 70% of the potential user population). It is envisioned that as many as ten independent carriers would provide EMS services of this type, with Xerox's proposed service being named XTEN, an acronym for Xerox Telecommunications Network.

Xerox's filing includes Appendix C titled "Basis for Market Projection." The appendix presents an analysis of the potential demand through 1990, at which point the top 200 metropolitan areas will require a total capacity estimated at $1.5 \times 10^{12}$ bits per second. Results are presented by year and by Standard Metropolitan Statistical Area (SMSA), and are also totaled in various ways. Demand is also related to type of service under the categories of Document Distribution, Data Communications, and Teleconferencing.

### DESCRIPTION

The model used to project communications requirements is basically demographic in that it relates demand to qualified population levels in each of the SMSA's. Population headcounts are projected from Commerce Dept. and Bureau of Labor Statistics and from Predicast Inc.'s Base Book for 1978 for Manufacturing, Distribution, Services, and Federal Government sectors. Selection criteria for workers in these four sectors are established and result in approximately 60% of the total population of workers in these sectors being qualified as eligible prospects for EMS services. A lesser group of five industries, (mining, contract construction, transportation and utilities, finance insurance and real estate, and state and local

government) are considered to offer 30% of their worker population as qualified prospects. The total prospect population by year is given as follows:

| Year | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| Qualified Prospects (millions of employees) | 38.2 | 42.8 | 46.3 | 48.4 |

These represent approximately 50% of all employees in the four and five industry groups cited above.

The sources indicated earlier were also used to relate qualified prospect populations to the various SMSA's as a function of year. Coverage of the top 200 cities is shown to include 70% of the qualified prospects. Some valuable data relating to the dispersal of American business establishments is also developed from Dun and Bradstreet, and Xerox proprietary sources. There are 873 companies and government agencies, each of which maintain at least 50 locations across the nation. Average employment at each site is approximately 90.

The demographic information described above is then applied to the projection of demand and market potential by year for each SMSA for each of three basic communications services:

a. Document Distribution
b. Data Communication
c. Teleconferencing

The method of estimating each, and a summary of the results obtained, is discussed below.

1. Document Distribution

It is predicted that this function will primarily be carried out by facsimile methods (requiring 200,000 to 1,000,000 bits per compressed page) or by means of coded text typically employing 8 bit ASCII characters (20,000 bits per page). The assumption is made that an average of 200,000 bits per page will apply for the composite mix of nodes.

XEROX CORPORATION
Nov. 16, 1977

The analysis begins with an Exhibit (C-6) of 1976 Document Distribution Volumes compiled from Xerox proprietary and other sources. The key figures are $50.7 \times 10^9$ intracompany document pages delivered per year and $20.5 \times 10^9$ pages per year of intercompany documents. All of the former and that fraction of the latter corresponding to qualified vs total head counts (approximately 50%) are considered as realizable potential for EMS delivery. The number of pages delivered is extrapolated through 1990, but unfortunately the basis for the extrapolation is not given. When reduced to a per qualified employee basis, the extrapolation is as per the first line in the table below with the following lines as a consequence.

| | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| Pages delivered annually per qualified prospect employee | 1372 | 1570 | 1718 | 1861 |
| Annual text bits ($\times 10^6$) per qualified employee (@ 200,000 bits/page) | 274 | 314 | 344 | 372 |
| Total prospective annual document distribution bits ($\times 10^{15}$) | 10.5 | 13.4 | 16.0 | 18.0 |

The appendix also presents a multiplication factor for the conversion of bits transmitted annually to capacity demand (data rate) in the peak busy hour. This factor is:

$$\frac{4 \times 2}{250 \text{ days/year} \times 20 \text{ hours/day} \times 3600 \text{ sec/hour}} = 44.4 \times 10^{-8}$$

The factor of 4 in the numerator allows for peaking and the factor of 2 accounts for the need for local distribution channels at each end of the transmission path. (With respect to a satellite link, using this factor would be equivalent to deriving the sum of up-link and down-link traffic).

The appendix also attempts to model market penetration by curve fitting to a Gomperz distribution ("s" shaped curve), but the procedure used is not clearly presented. Essentially, however, it is assumed that EMS services will level off at 15 percent of the realizable potential document delivery traffic by about the year 2000.

2. Data Communications

The document expresses concern over the ability to accurately estimate the total amount of U. S. Business and Government data traffic that conceivably could be communicated. It nevertheless proceeds by accepting estimates made by Edward Collyer, AT&T's Product Manager, for Data Network Services for transmission revenue in billions of dollars for years ranging between 1965 and 1985. Using a conversion factor of $2.00 per million bits and extending the results to 1990, the data presented in the first line of the following table are arrived at. The second line is obtained by combining the first with the qualified population head count data presented earlier.

| | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| Data bits transmitted per year ($\times 10^{15}$) | .85 | 1.60 | 2.75 | 4.40 |
| Annual Bits per qualified prospect employee ($\times 10^{6}$) | 22.2 | 37.3 | 59.4 | 90.9 |

The results summarized above are also broken down by SMSA, by year. The factor of $44.4 \times 10^{-8}$ is again employed to translate annual data bits to capacity demand in bits per second during the peak busy hour. A curve fitting to a Gomperz curve is used to estimate market projection from the realizable potential discussed above. For this data communications service it is predicted that the EMS market share will level off at about 25% of realizable potential by the year 2000.

3. Teleconferencing

The appendix indicates that to date audio, video and graphic communications techniques enabling effective meetings of geographically separated participants has had only limited success. It projects, however, that this role for communications will become significant as the costs of energy, travel, and labor rapidly increase.

The appendix quotes a reference by Pye and Williams in Telecommunications Policy (June 1977) in support of the position that a level of teleconferencing somewhere between full video and straight audio will be most effective for meeting future teleconferencing needs. Such a level would typically consist of:

a. Two-way audio channels, connecting all meeting sites

b. High quality still-frame video at one frame every few seconds.

c. Retrieval and display of information from computer data bases.

d. Immediate facsimile reproduction of exhibits in hard copy.

The analysis of realizable potential begins with estimates made by SRI and Canadian survey sources that:

a. Roughly 8% of all U.S. air travel (20% of business trips by air) could be replaced by suitable audio/graphic services.

b. An average of 2 people take each business trip.

c. An average of 2.7 meetings are held per trip.

d. An average of 4 hours is spent per meeting.

From these assumptions it follows that:

$$\frac{\text{Potential No. of Teleconferences}}{\text{Number of Emplanements}} = \frac{.08 \times 2.7}{2 \times 2} = .054$$

Allocating 50 Kbps for still-frame video plus 16 Kbps for two-way voice transmission for a total of 66 Kbps, results in 950 million bits for each four hour conference.

The number of annual revenue passenger emplanements is projected by year through 1990 (source not stated) and combined with the population headcounts presented earlier. The factors discussed above are then used to derive the following estimates:

| | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| U.S.Revenue Passenger Emplanements (x $10^6$) | 195 | 234 | 304 | 383 |
| Potential Teleconferences per year (x $10^6$) | 11 | 13 | 17 | 21 |
| Annual Teleconferencing bits (x $10^{15}$) | 10.1 | 12.2 | 15.7 | 19.8 |
| Annual Teleconferencing bits per qualified prospect employee (x $10^6$) | 264 | 285 | 340 | 409 |

The results summarized above are broken down by SMSA, by year. The factor $44.4 \times 10^{-8}$ is again employed to translate annual data bits to capacity demand in bits per second during the peak busy hour. Curve fitting to a Gomperz curve is used to estimate market projection from the realizable potential discussed above. For teleconferencing it is predicted that the EMS market share will level off at about 10 percent of realizable potential by the year 2000.

4. Summarized Results

The results for the three services are summarized below.

| | 1975 | 1980 | 1985 | 1990 |
|---|---|---|---|---|
| Document Distribution Bits Annually, ($\times 10^{15}$) | 10.5 | 13.4 | 16.0 | 18.0 |
| Data Communications Bits Annually, ($\times 10^{15}$) | .9 | 1.6 | 2.8 | 4.4 |
| Teleconferencing, Bits Annually ($\times 10^{15}$) | 10.1 | 12.2 | 15.7 | 19.8 |
| Total Bits Annually ($\times 10^{15}$) | 21.5 | 27.2 | 34.5 | 42.2 |
| Peak Busy Hour Bits per Sec ($\times 10^{9}$) (Multiply above by $44.4 \times 10^{-8}$) | 9.5 | 12.1 | 15.3 | 18.7 |
| *Projected Market Share for EMS (from Gomperz curves) Annual Bits $\times 10^{15}$ Top 200 SMAS. | - | .007 | 1.0 | 3.3 |

*From Exhibit C-18 P.30C by dividing by $44.4 \times 10^{-8}$

XEROX CORPORATION
Nov. 16, 1977

COMMENTS

The procedure used (evaluating realizable potential in terms of demographic projections) is a valid and useful approach. The selection criteria by industrial sector, however, appears somewhat capricious. The percentage of total U.S. employment in each of the sectors that was selected as qualified prospects is as follows:

| | | |
|---|---|---|
| 1. | Manufacturing | 90% |
| 2. | Distribution | 50% |
| 3. | Services | 21% |
| 4. | Federal Government | 98% |
| 5. | Mining | 30% |
| 6. | Contract Construction | 30% |
| 7. | Transportation and Utilities | 30% |
| 8. | Finance, Insurance and Real Estate | 30% |
| 9. | State and Local Government | 30% |

The relatively low impact accorded to Finance (which presumably includes the heavily communications oriented banking community) as opposed to manufacturing deserves some further investigation. Similarly, Transportation and State Government requirements are possibly under-represented.

The services analyzed (Document Distribution, Data Communications, and Teleconferencing) are certainly the motivators of a major portion of demand, but it should be noted that TV distribution with its exceptionally wide bandwidth requirements has not been included in the derived projections.

In projecting communication demands resulting from document distribution requirements, a critical item is the number of bits required per page. The basic issue of whether the page is primarily treated as an image requiring 200,000 to 1 million bits or as data requiring 10 to 20 Kilobits has order of magnitude impact on projected traffic. The Xerox filing assumes an intermediate value of 200,000 bits per page, which is probably reasonable pending future development of office of the future, fax vs communicating word processor, usage patterns.

The projection for data communications follows a simplistic approach, being based essentially on unsupported projections of Bell System revenue estimates and a $2.00 per megabit conversion factor. However, to a certain extent the estimate for this service is better founded than the other two in that data communications is further advanced and therefore historical data on actual usage exists. The usage of the other two services is more speculative. It is interesting to note that data communications services account for only about 4 to 10 percent of the total realizable potential.

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The projection of realizable potential for teleconferencing uses displacement of business travel as an estimation method. Key items to note are a factor of 2.7 to account for multiple conferences on the same business trip, and the assumption that 66 Kbps will be sufficient to support the audio/graphic communications channels required. This specifically excludes full video transmission as an important element in future teleconferencing.

The factor used to convert between annual bits and peak busy hour demand in bits per second has implicit in it a 4 to 1 peaking factor and a 20 hour day, plus an additional factor of two to account for terrestrial distribution at both ends of the link. When applying these results to other applications, this factor should be reevaluated in light of the assumptions appropriate to the new application.

Telephone discussions with Xerox personnel associated with the filing gave some additional insight into satellite aspects of the filing that are not covered in the written material. While the transponders will be leased from satellite common carriers, Xerox expects to supply the earth stations. They estimate that relay from office buildings to the local/city node via terrestrial microwave will not always result in a traffic pool at that local/city node of sufficient magnitude to justify a full TDMA earth station ($62 \times 10^6$ bits per second per transponder). These smaller nodes will therefor use Single Channel Per Carrier earth stations (achieving only about $17 \times 10^6$ bits per second per transponder) and will be satellite relayed to a larger city prior to a second relay over a satellite TDMA link on its way to its destination. If the multihop approach advocated by Xerox prevails, the resultant demand for satellite transponders may be several times that which would otherwise be required on the basis of the traffic demands.

# 30/20 GHz Satellite Trunking Costs

# 30/20 GHZ SATELLITE TRUNKING COSTS

## 1.0 INTRODUCTION

This annex to the main study report produced under NASA Contract Number NAS 3-21366 deals with the costs of 30/20 GHz satellite trunking systems and compares these costs with those of a terrestrial communication system. The forecast period, 1980 to 2000, used in the main study report is applicable here. Costs for the 30/20 GHz satellite system segments developed by Ford Aerospace and Communications Corporation under a companion NASA contract are used in this analysis.

The scope of the analysis includes the cost of the space, ground, and supporting terrestrial segments. Costs are projected to the year anticipated for saturation of domestic satellite capability in the C and Ku bands (i.e., 1989). This year is then used as the start of operation of 30/20 GHz satellites, and the cost analysis carries forward circuit costs for a fourteen year period beyond 1989. The scheduled implementation of additional 30/20 GHz satellites is based on the traffic projections given in the main report.

The 30/20 GHz satellite system configuration used in the pricing analysis includes ten pairs of diversity earth stations and a multiple beam satellite using ten reusable radio frequency carriers, each having a bandwidth of 2.5 GHz. This configuration is based on the engineering analysis presented by Ford Aerospace at the joint presentation given at the NASA Lewis Research Center on June 6, 1979.

## 2.0 ASSUMPTIONS

The cost analysis of the 30/20 GHz Communications Satellite System uses the following assumptions:

a. The average circuit length is 890 miles. This figure is used uniformly for deriving circuit mile costs for terrestrial and satellite media, and is based on average intertoll circuit length statistics for voice channels in 1976.

b. Each 30/20 GHz satellite can handle a total capacity of 25 Gbps of traffic by use of ten frequency reusable spot beams.

c. Maximum traffic handled by a satellite will not exceed 90 percent of capacity in order to provide for dynamic shifts in demand, reserve capacity, and redundancy protection.

d. The average distance between earth stations and the supporting distribution points, (e.g., telephone central office), is 50 miles. This segment of the circuit is referred to as a terrestrial tail.

e. Terrestrial tails are implemented by means of microwave radio facilities and are used by both satellite and terrestrial long haul systems for local distribution.

f. Satellite life is estimated to be seven years, earth stations 14 years, and tracking, telemetry and control facilities, 14 years. Supporting terrestrial communications facilities are estimated to have a life of 21 years.

## 3.0 30/20 GHZ SATELLITE SYSTEM COSTS

This section explains the derivation of the costs per channel mile for a voice circuit implemented by use of a 30/20 GHz satellite for long haul trunking.

### 3.1 SYSTEM CHARACTERISTICS

The basic design characteristics of the 30/20 GHz satellite system are derived from the Ford Aerospace effort referred to in Section 1. The major points are summarized as follows:

| | | | |
|---|---|---|---|
| a. | Number of spot beams | : | 10 |
| b. | Total satellite data rate | : | 25 Gbps |
| c. | Bandwidth per beam | : | 2.5 GHz |
| d. | Earth Stations | : | 10 pair of space diversity trunking sites, each with 12 meter antennas. |
| e. | Satellite per channel rate | : | 274 Mbps |
| f. | Launch Vehicle | : | Shuttle/SSUS - A |

## 3.2 SATELLITE AND EARTH SYSTEM COSTS

Ford Aerospace derived costs are based on a four satellite development, three launches, a TT&C facility, and ten pair of space diversity earth stations. These costs are summarized in Table 1 below.

TABLE 1. 30/20 GHZ SATELLITE SYSTEM COSTS

| Item | Number | Cost* |
|---|---|---|
| Spacecraft | 4 | $195M |
| Launch and perigee motor | 3 | 57M |
| TT&C | 1 | 38M |
| Earth Stations | 10 Pair | 78M |
| Total Capital Costs** | | $368M |
| Recurring Costs | | $5.7M/Yr. |
| Additional Spacecraft | | $27M/each |
| Additional Launches | | $19M/each |

*Based on 1978 costs
**Based on first costs - includes development.

## 3.3 TRAFFIC DEMAND FOR 30/20 GHZ FACILITIES

Section 6 of the main report presents the satellite suitable traffic demand predicted for the years 1980 to 2000 in terms of equivalent satellite transponders. The main report indicates that if all satellite capturable traffic was satisfied by C and Ku-band systems, these systems would saturate in about 1989. This is based on a "most probable" scenario which predicts that 648 36 MHz C and Ku-band transponders will be available for use by domestic telecommunication carriers.

Satellite suitable traffic in excess of that transmitted by means of C and Ku band satellites is assumed to be available to the 30/20 GHz system. Table 2 presents the yearly traffic demand from the C and Ku saturation year of 1989 to the year 2002, a fourteen year period. The table shows that the satellite capturable traffic demand in the initial operational year of 1989 will support a total of 10,000 circuits. This will grow to 415,000 circuits in the year 2002 as determined in the analysis below.

TABLE 2. SATELLITE SUITABLE TRAFFIC DEMAND

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transponders | | | | | | | | | | | | | | |
| Sat. Suitable Traffic | 590 | 690 | 790 | 870 | 910 | 940 | 970 | 1000 | 1030 | 1060 | 1090 | 1120 | 1130 | 1140 |
| C & Ku Band Capacity | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 | 648 |
| Excess Traffic | - | 42 | 142 | 222 | 262 | 292 | 322 | 352 | 382 | 412 | 442 | 472 | 482 | 492 |
| Transponder Conversion Rate, Mbps | 72 | 72 | 80 | 90 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 |
| Excess Traffic in Gbps | - | 3.0 | 11.4 | 20.0 | 28.3 | 31.5 | 34.8 | 38.0 | 41.3 | 44.5 | 47.7 | 51.0 | 52.1 | 53.1 |
| Circuits Required (000s) | 10 | 25 | 90 | 156 | 218 | 245 | 272 | 296 | 323 | 350 | 374 | 397 | 403 | 415 |
| Launch Schedule | #1 | | | | #2 | | | #3 | | #4 | | #5 | | |
| 30/20 GHz Circuits Available, (000s) | 195 | 195 | 195 | 195 | 389 | 389 | 389 | 389 | 389 | 584 | 584 | 584 | 584 | 584 |
| Sat. Fill Factor | | | | | | | | | | | | | | |
| Satellite #1 | 0.05 | 0.12 | 0.46 | 0.8 | 0.9 | 0.9 | 0.9 | | | | | | | |
| Satellite #2 | | | | | 0.23 | 0.36 | 0.49 | 0.9 | 0.9 | 0.9 | 0.9 | | | |
| Satellite #3 | | | | | | | | 0.62 | 0.75 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Satellite #4 | | | | | | | | | | 0 | 0.11 | 0.9 | 0.9 | 0.9 |
| Satellite #5 | | | | | | | | | | | | 0.24 | 0.28 | 0.32 |
| Average Fill Factor | 0.05 | 0.12 | 0.46 | 0.8 | 0.56 | 0.63 | 0.70 | 0.76 | 0.83 | 0.6 | 0.64 | 0.68 | 0.69 | 0.71 |

## 3.4 CIRCUIT DEMAND FORECAST

The demand forecast for 30/20 GHz satellite derived circuits uses the following factors and assumptions.

### 3.4.1 USER SERVICES

Although total traffic demand includes voice, video and data services, the traffic has been converted to equivalent digital voice circuits. This permits cost comparisons of competing media to be made on a common basis.

### 3.4.2 VOICE CIRCUIT DATA RATE

The current T1 carrier voice band digital rate of 64 Kbps is used throughout the analysis to derive voice circuits from total digital traffic. The T1 carrier voice band rate is rapidly becoming the North American standard and represents the vast majority of current commercial digital installations. The full quantity of equivalent digital voice circuits that can be handled by a 30/20 GHz satellite, therefore, is determined by dividing the total digital capacity of 25 Gbps by the data rate of a single digital voice band as follows:

$$\frac{\text{Total Satellite Capacity} = 25 \times 10^9 \text{ bps}}{\text{Data Rate per Channel} \quad = 64 \times 10^3 \times 2} = 195{,}000$$

The factor of two in the denominator converts voice channel capacity to two-way channels.

### 3.4.3 SATELLITE FREQUENCY ASSIGNMENT CONFIGURATION

To load a 30/20 GHz satellite to its full capacity of 25 Gbps requires that each of the ten earth station pairs handle their full capability of 2.5 Gbps of traffic. In practice, it is unlikely that the available traffic will be equally distributed throughout the ten sites. The premise of equal distribution is used, however, in determining the full potential capacity of each 30/20 GHz satellite since this represents the maximum capacity.

### 3.4.4 FILL FACTORS

The fill factor measures the utilization efficiency of the satellite systems' ultimate capacity. As the fill factor increases, the need for an additional satellite is indicated. Table 2 shows, for example, that in 1991 the traffic demand for satellite transmission capability in excess to that provided by C and Ku band satellites, is 11.4 Gbps. When this is compared

to the 30/20 GHz satellite's full capacity of 25 Gbps, the fill factor is 0.46. The fill factor for the satellite system is not expected to exceed 0.9 because of distribution, redundancy and back-up facility factors as given under assumptions. Average fill of the system, with the use of two or more satellites, should not exceed a total system capacity of 0.9 when the capacity of all satellites is cumulatively added. The analysis schedules launchings of new 30/20 GHz satellites to assure that the maximum fill factor is not exceeded.

## 3.5 CIRCUIT MILE COSTS

The derivation of circuit mile costs for a 30/20 GHz satellite derived circuit is divided into two segments: (1) long haul trunk via a 30/20 GHz satellite; and (2) short haul microwave radio terrestrial tail. Both segments are discussed below.

### 3.5.1 LONG HAUL COSTS

Having established 30/20 GHz satellite suitable traffic demand on a year-by-year basis in Table 2, Table 3 provides a corresponding annual forecast of costs for the same period. Launchings are scheduled at the time justified by the anticipated increase in demand or at the time required for satellite replacement due to the seven year life expectancy. Table 3 presents annualized cost figures for both capital and recurring costs for the fourteen year time period from 1989 to 2002.

The costs for all launchings include both the payload (i.e., satellite) and booster vehicle associated with space shuttle launching as shown in the Ford Aerospace figures. Launching for satellites 1 through 4 cost 9.7 million dollars per year each, when put on an annual cost basis for a satellite life expectancy of seven years. The fifth satellite cost less since the development costs have been shared by the previous four satellites. Table 1 places the cost of the additional spacecraft at 27 million dollars, and the launch at 19 million dollars. Using the same seven year life expectancy results in an annual cost of 6.6 million dollars.

The earth station costs shown in Table 1 are ammortized over a fourteen year period, resulting in an annual cost of 5.6 million dollars for the full period of 1989 to 2002. Similarly, the TT&C cost of 38 million dollars shown in Table 1, when put on an annual basis, results in a cost of 2.7 million dollars per year. Operating expenses are estimated to be 5.7 million dollars per year for the earth stations and TT&C sites over the fourteen year period. All costs are in 1978 dollars.

The calculation of the average equivalent voice circuit cost of a 30/20 GHz satellite derived circuit is accomplished by dividing the average number of voice circuits, 64 Kbps per circuit, into the total costs for each year of operation. Over the fourteen year period from 1989 to 2002, Table 3 shows the average cost per circuit per year to be 350 dollars. Using the same average circuit mile length of 890 miles shown in the main report, results in a cost of $0.40 per voice circuit mile per year.

TABLE 3. 30/20 GHz SATELLITE DERIVED CIRCUIT COSTS

| | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cost Item (Millions of Dollars) | | | | | | | | | | | | | | | |
| Satellite #1 (1) | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | | | | | | | | 68 |
| Satellite #2 (1) | | | | | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | | | | 68 |
| Satellite #3 (1) | | | | | | | | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 68 |
| Satellite #4 (1) | | | | | | | | | | 9.7 | 9.7 | 9.7 | 9.7 | 9.7 | 49 |
| Satellite #5 (1) | | | | | | | | | | | | 6.6 | 6.6 | 6.6 | 20 |
| TT&C | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 38 |
| Earth Stations | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 78 |
| Total Capital Costs | 18.0 | 18.0 | 18.0 | 18.0 | 27.7 | 27.7 | 27.7 | 27.7 | 27.7 | 37.4 | 37.4 | 34.3 | 34.3 | 34.3 | 389 |
| Total Recurring Costs | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 5.7 | 80 |
| Total Costs | 23.7 | 23.7 | 23.7 | 23.7 | 33.4 | 33.4 | 33.4 | 33.4 | 33.4 | 43.1 | 43.1 | 40.0 | 40.0 | 40.0 | 469 |
| Average Circuits in Use (000s) | 10 | 25 | 90 | 156 | 218 | 245 | 272 | 296 | 323 | 350 | 374 | 397 | 403 | 415 | |
| Cost per Circuit (2) | 2370 | 948 | 263 | 152 | 153 | 136 | 123 | 113 | 103 | 123 | 115 | 101 | 99 | 96 | |
| Average Cost per Circuit, per year (2) | | | | | | | | | | | | | | | 350 |
| Average Cost per Circuit Mile, per year (3) | | | | | | | | | | | | | | | 0.40 |

Notes: (1) Annualized satellite costs include cost of launch
(2) Cost in dollars for digital equivalent voice circuit
(3) Based on an average terrestrial circuit length of 890 miles.

### 3.5.2 TERRESTRIAL TAIL COSTS

In addition to the satellite segment, the end-to-end circuit includes two terrestrial tails and the central office equipment required for local distribution. An average terrestrial tail distance of 50 miles is assumed as was done in the main report. The terrestrial tail is assumed to utilize digital microwave radio at each end between the earth station and the local central office.

Based on the data from Section 5 of the main report, the tail costs are summarized below and include both transmission and central office costs. All costs are on an annual basis, including both capital and recurring costs, and are expressed in dollars per circuit mile per year based on the figures for the year 1990. To derive per mile costs for central office equipment a total circuit distance of 890 miles is used.

| | |
|---|---|
| Transmission - Digital microwave radio | $2.03 |
| Central Office - Based on 890 mile circuit | 2.53 |
| Total ($/Circuit mile/Year) | $4.56 |

### 3.5.3 TOTAL END-TO-END CIRCUIT COSTS

The end-to-end circuit costs for the digital voice circuit includes the long haul trunk derived from the 30/20 GHz satellite system, the two local terrestrial tails at each end, and the central office equipment used for local distribution. As given above, the long haul segment is taken as 890 miles, and each terrestrial tail end is 50 miles.

Table 4 summarizes the costs for this "average" circuit. All costs are annual and expressed on circuit mile basis for a digital equivalent voice circuit for the year 1990.

TABLE 4. SUMMARY OF 30/20 GHZ SATELLITE DERIVED VOICE CIRCUIT COSTS - 1990 PROJECTION

| Cost Item | Cost per Circuit Mile | Effective Route Miles | Cost Per Circuit |
|---|---|---|---|
| 30/20 GHz Satellite Link | $0.40 | 890 | $356 |
| Microwave Tail Link - 2 | 2.03 | 100 | 203 |
| Central Office Equipment | 2.53 | 890 | 2,252 |
| Total Cost per Average Circuit | | | $2,811. |

## 4.0 COMPARISON OF TERRESTRIAL AND 30/20 GHZ SATELLITE CIRCUIT COSTS

The costs for a terrestrial voice circuit are developed in Section 5 of the main report. The 1976 estimated cost, including both annualized capital costs and recurring costs, is $4.93 per voice circuit mile per year. Projecting this figure to 1990 results in an annual cost of $4.28 per circuit mile. Extending the cost to the average length circuit of 890 miles results in a total cost of $3,809 per year.

Table 4 indicates that the comparative cost for a 30/20 GHz satellite derived circuit for 1990 is $2,811 per voice circuit mile per year. The 30/20 GHz satellite derived circuit, therefore, is estimated to be 26 percent cheaper than the comparative terrestrial circuit.

It is also interesting to note that a direct-to-user (DTU) circuit would eliminate the need for terrestrial tails and central office equipment. Thus, a direct-to-user satellite application appears to be an attractive alternative. The actual cost of a DTU circuit, however, is highly dependent upon the costs of the rooftop (or backyard) earth station and the expenses associated with its operation, maintenance and support. Furthermore, the viability of a DTU installation depends on the amount of traffic available to and from the user.